How do large-scale agricultural investments affect land use and the environment on the western slopes of Mount Kenya? Empirical evidence based on small-scale farmers' perceptions and remote sensing

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Abstract

Africa has been heavily targeted by large-scale agricultural investments (LAIs) throughout the last decade, with scarcely known impacts on local social-ecological systems. In Kenya, a large number of LAIs were made in the region northwest of Mount Kenya. These large-scale farms produce vegetables and flowers mainly for European markets. However, land use in the region remains dominated by small-scale crop and livestock farms with less than one hectare of land each, who produce both for their own subsistence and for the local markets. We interviewed 100 small-scale farmers living near five different LAIs to elicit their perceptions of the impacts that these LAIs have on their land use and the overall environment. Furthermore, we analyzed remotely sensed land cover and land use data to assess land use change in the vicinity of the five LAIs. While land use change did not follow a clear trend, a number of small-scale farmers did adapt their crop management to environmental changes such as a reduced river water flows and increased pests, which they attributed to the presence of LAIs. Despite the high number of open conflicts between small-scale land users and LAIs around the issue of river water abstraction, the main environmental impact, felt by almost half of the interviewed land users, was air pollution with agrochemicals sprayed on the LAIs' land. Even though only a low percentage of local land users and their household members were directly involved with LAIs, a large majority of respondents favored the presence of LAIs nearby, as they are believed to contribute to the region's overall economic development.

Keywords: Laikipia County; land use change; large-scale agricultural investments; social-ecological systems; spillovers

1. Introduction

The global land rush, fueled by the 2007–2008 global food price crisis, has targeted Africa more than any other continent (The World Bank, 2011). Today, implemented land deals in Africa cover about 10 million hectares (Nolte et al., 2016). Agricultural investments into what is often considered "idle" or "underused" land have been propagated as potential win–win situations that enable an increase in agricultural production while at the same time alleviating poverty (Collier and Dercon, 2014). Whether current large-scale agricultural investments (LAIs) can live up to these expectations largely depends on the type of impacts and spillover effects they have on small-scale farmers living in their vicinity (Deininger and Xia, 2016). Even though the phenomenon of LAIs has attracted widespread attention, and despite concerns about small-scale farmers losing access to land and other vital livelihood resources and LAIs leading to environmental degradation, only few studies have comprehensively examined the impacts of LAIs on small-scale farmers' land use and livelihoods.

Unlike the Land Matrix Initiative (Nolte et al., 2016), we interpret the word "large-scale" in "large-scale agricultural investments" as referring not only to the size of the cultivated area, but also to economic size in terms of capital involved and labor employed. Accordingly, in the context of this study, an LAI need not necessarily cover a large area if it involves a great amount of capital or has a large number of employees.

To date, studies on the impacts of LAIs have looked mainly at how LAIs affect the labor market, finding in many cases that small-scale farmers benefit from employment generation (The World Bank, 2014). One frequently anticipated positive spillover is the adoption of improved agricultural practices by small-scale farmers as they acquire new skills and knowledge while working for LAI enterprises. This hypothesis was supported by Deininger and Xia (2016), who analyzed agricultural census data for Mozambique and found that spillover effects further included access to inputs and demand for labor. In a case study in Ethiopia, Negash and Swinnen (2013) observed increased food productivity on small-scale farms due to income generated through sales of biofuel crops.

A global meta-analysis showed that adverse impacts of LAIs on livelihoods mainly included loss of access to land and natural resources, increased conflicts, and material or procedural inequality within communities (Oberlack et al., 2016). German et al. (2013) looked at four cases of LAIs in Africa and found the main negative impact of LAIs on smallholders to be smallholders' loss of customary land rights. In terms of environmental impacts, an increase in water scarcity is the most frequently anticipated adverse effect, as it was shown that access to water resources is an important factor in the choice of the location of a future LAI (Breu et al., 2016; Rulli et al., 2013). Nevertheless, only few studies so far have investigated the empirical impacts of LAIs on local water availability and quality (except Muriithi and Yu, 2015; von Maltitz et al., 2016). Furthermore, the understanding of LAI impacts on other ecosystem services remains limited. LAIs may affect ecosystem services not only directly, for example when diversified extensively used cropland is converted into an intensively managed monocultural plantation, but also indirectly, due to changes in small-scale farmers' crop management or the displacement of land use activities. Populations living in the vicinity of rice and teak production companies in Tanzania observed that the LAI had blocked wildlife migration routes (Johansson and Isgren, 2017). In Ghana, small-scale farmers' loss of land to jatropha companies forced them to shorten fallow periods on their remaining land and consequently led to soil degradation (Acheampong and Campion, 2014; Schoneveld et al., 2011). Direct and indirect impacts on land use were observed in Zambia, where smallholders introduced jatropha on their plots and established new plots in forest areas to cultivate displaced food crops (German et al., 2011). In Mozambique, biodiversity-rich *miombo* woodlands were cleared for jatropha plantations, decreasing ecosystem services provision by these woodlands (von Maltitz et al., 2016).

Kenya's agricultural sector has focused considerably on export since colonial times (Deininger and Binswanger, 1995). Kenya is also among those African countries that both domestic and foreign private agricultural investors target (FIAN, 2010). Nevertheless, smallholders' agricultural production accounts for 75% of the country's total agricultural output (Government of Kenya, 2010). Along with the area around Naivasha (Kirigia et al., 2016), Laikipia County on the western slopes of Mount Kenya is one of the prime areas for flower and vegetable production. In the past century, this region underwent several dramatic land use and socio-economic transitions. First, land use changed from pastoralist to colonial large-scale farming and ranching; then, it changed back to small-scale uses after the postcolonial subdivision of former large-scale ranches and the immigration of peasant households (Wiesmann, 1998); and starting in the late 1980s, it shifted towards highly technicized export-oriented greenhouse agriculture by commercial horticulture and floriculture farms (Kiteme et al., 2008). Their produce is mainly exported to European markets to satisfy consumers' demand for year-round fresh vegetables and flowers (Dolan, 2005). In 2013, 35 LAIs were producing mainly vegetables (broccoli, runner beans, kale, French beans, etc.) and flowers (mainly roses) for export to European markets (Lanari et al., 2016). The expansion of LAIs along the western slopes of Mount Kenya exacerbated water scarcity in the area—especially in the dry season, which coincides with peaks in European consumer demands, leading to conflicts (Wiesmann et al., 2000). However, while overall water use in the dry season has increased, the reliance on river water has decreased. In 2013, only 10–31% of the water used by the floriculture and horticulture sectors during the dry seasons was taken from rivers, while the rest was sourced from ground- and storage water (Lanari, 2014). A study based on qualitative interviews with small-scale farmers in the same area showed that over-abstraction of river water and the pollution of water sources with chemicals were the two main environmental impacts that small-scale farmers attributed to LAIs (Ulrich, 2014). Muriithi and Yu (2015) measured water quality in selected rivers in Laikipia and Meru and found that total dissolved solids, electrical conductivity, and salinity had increased in concentration and traces of cadmium, phosphates, and zinc were present near large-scale intensive horticulture farms. However, while the livelihood systems of small-scale farmers in the region have been studied intensively for more than 20 years (Kohler and Wiesmann, 2003; McCord et al., 2015; Ogalleh et al., 2012; Roden et al., 2016; Ulrich et al., 2012; e.g. Wiesmann, 1992), little is known about how land use has changed in the surroundings of LAIs and how small-scale farmers have adapted their land use in the context of LAIs. While it is assumed that part of the local population has been temporarily employed by LAI companies, it remains unknown whether these households have adopted new agricultural practices and applied them on their own farms.

Therefore, the aim of this study was to identify perceived impacts of large-scale floriculture and horticulture farms on small-scale farmers' land use and on the overall environment on the western slopes of Mount Kenya. Based on the analysis of interview data and remotely sensed spatial data, we sought to answer the following research questions: (1) To what extent, and how, did small-scale farmers change their land use, and are these changes related to the presence of LAIs in their neighborhood? (2) Which direct environmental impacts do small-scale farmers perceive LAIs to have? (3) Do small-scale farmers perceive LAIs to have had off-site impacts on land use, and if so, can we confirm this by remote sensing? The overall goal was to provide more comprehensive evidence regarding direct and indirect impacts of LAIs on social-ecological systems northwest of Mount Kenya.

2. Material and methods

2.1. Study area

Our study area is situated on the western slopes of Mount Kenya, within the upper Ewaso Ng'iro basin, and includes parts of Laikipia, Meru, and Nyeri counties (Fig. 1). Climatic conditions range from semihumid (1,000–1,500 mm of rainfall annually) near Mount Kenya in the east to semiarid (400–900 mm rainfall) and arid (about 350 mm rainfall) towards the west (Berger, 1989). Two distinct rainy seasons determine the cropping calendar, with long rains lasting from mid-March to mid-June (sowing and planting time) and short rains from mid-September to the end of December. The majority of the rural population are small-scale farmers; on less than one hectare of land per household, they practice a combination of crop farming and livestock keeping, mostly for subsistence but partly also for sale on local markets. In the drier lowland areas, purely pastoral systems dominate. The towns of Nanyuki, Naro Moru, and Timau are the area's main economic centers. The presence of LAIs has increased considerably, from 24 in 2003 to 35 in 2013 (Lanari, 2014); this development has been coupled with the emergence of a remarkable number of greenhouses and open water bodies (Eckert et al., 2017; Lanari et al., 2016). To assess the impacts of LAIs on small-scale farmers' land use, we selected five of the total 35 LAIs in our study area for closer analysis. We did a purposive sampling, with the aim of representing the two main types of LAI—floriculture and horticulture—as well as the gradients of rainfall and altitude in the study area (Table 1). Two of the sampled LAIs produce vegetables, the other three produce flowers. All of them export their produce. The five LAIs were established between 2000 and 2013.

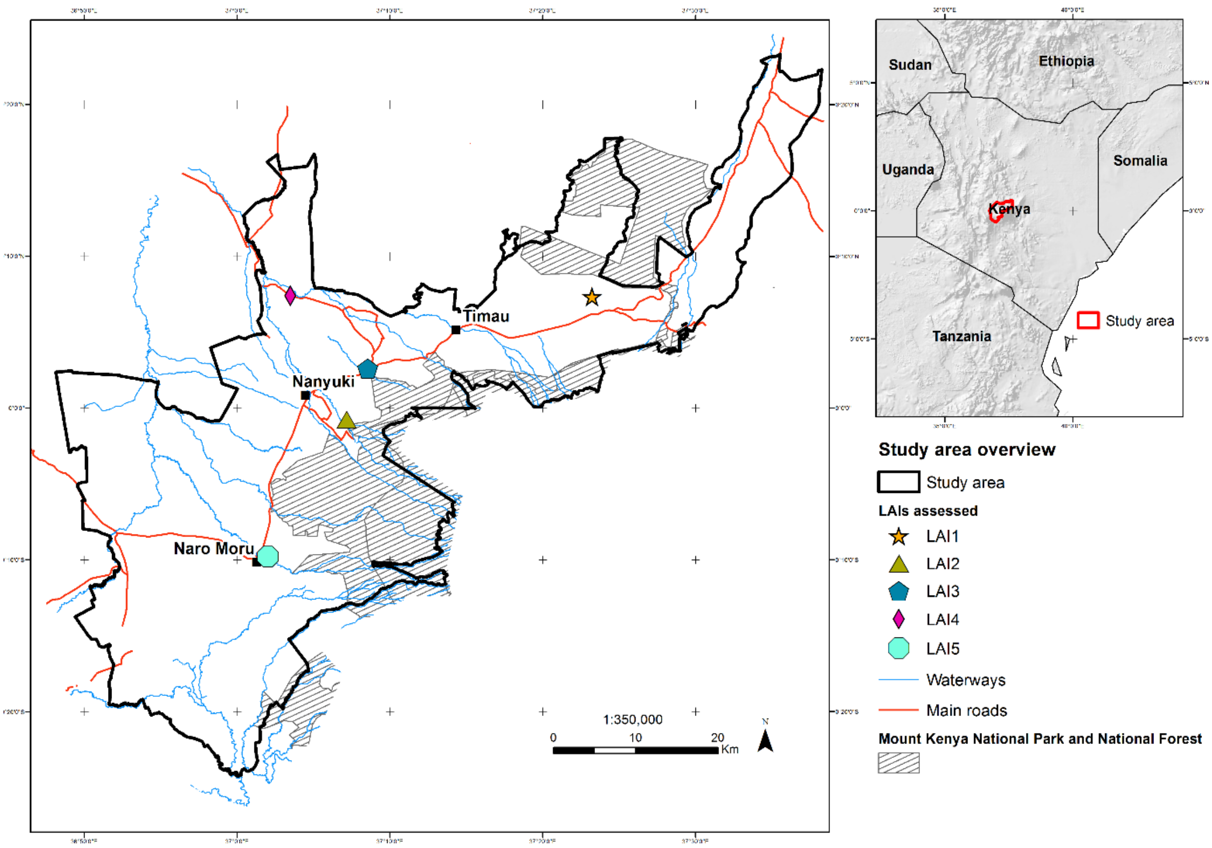

Fig. 1. Study area on the western slopes of Mount Kenya, with the five LAIs assessed, as well as major towns, roads, waterways, and the Mount Kenya National Park and National Forest. Adapted from Eckert et al. *(2017)*.

Table 1. Characteristics of LAIs analyzed (own data from interviews with LAI farm managers).

	LAI1	**LAI2**	**LAI3**	**LAI4**	**LAI5**
Crops produced	Flowers	Flowers	Flowers	Vegetables	Vegetables
Water sources for irrigation	Groundwater, rainwater harvesting	River, rainwater	Rainwater harvesting,	River	Groundwater, river,

		harvesting, groundwater	borehole, river		rainwater harvesting
Biodiversity management	Hedges	Crop diversification	n.a.	Tree planting	Tree planting
Rainfall (mm/year)	600–800	800–1200	600–800	600–800	800–1200
Mean elevation (m)	2426	2063	2019	1807	1993
Year established	2013	2003	2009	2005	2000

2.2. Conceptual framework

As we aimed to identify both direct and indirect environmental impacts of LAIs, we differentiated between on-site and off-site land use changes induced by LAIs (Fig. 2). The establishment of an LAI enterprise mostly leads to a change in land use on-site (e.g. from shrubland to intensive horticultural production). These land use changes may have impacts on ecosystem services such as surface water availability, climate regulation, and biodiversity. Such changes in ecosystem service provision (e.g. water availability) can then impact on small-scale farmers' land use, for example by causing them to reorganize their farming systems or to adapt their irrigation practices. Furthermore, LAIs can influence small-scale farmers' land management practices directly, for example via technology transfer or by improving access to agricultural inputs. The changes occurring on small-scale farmers' land also have impacts on ecosystem services. In our analysis of off-site land use changes and their impacts, we considered the three main land covers and land uses in the study area: cropland, grazing land, and tree cover (natural forest and plantations). Not shown in Fig. 2 are non-environmental impacts of LAIs on smallholders' livelihoods.

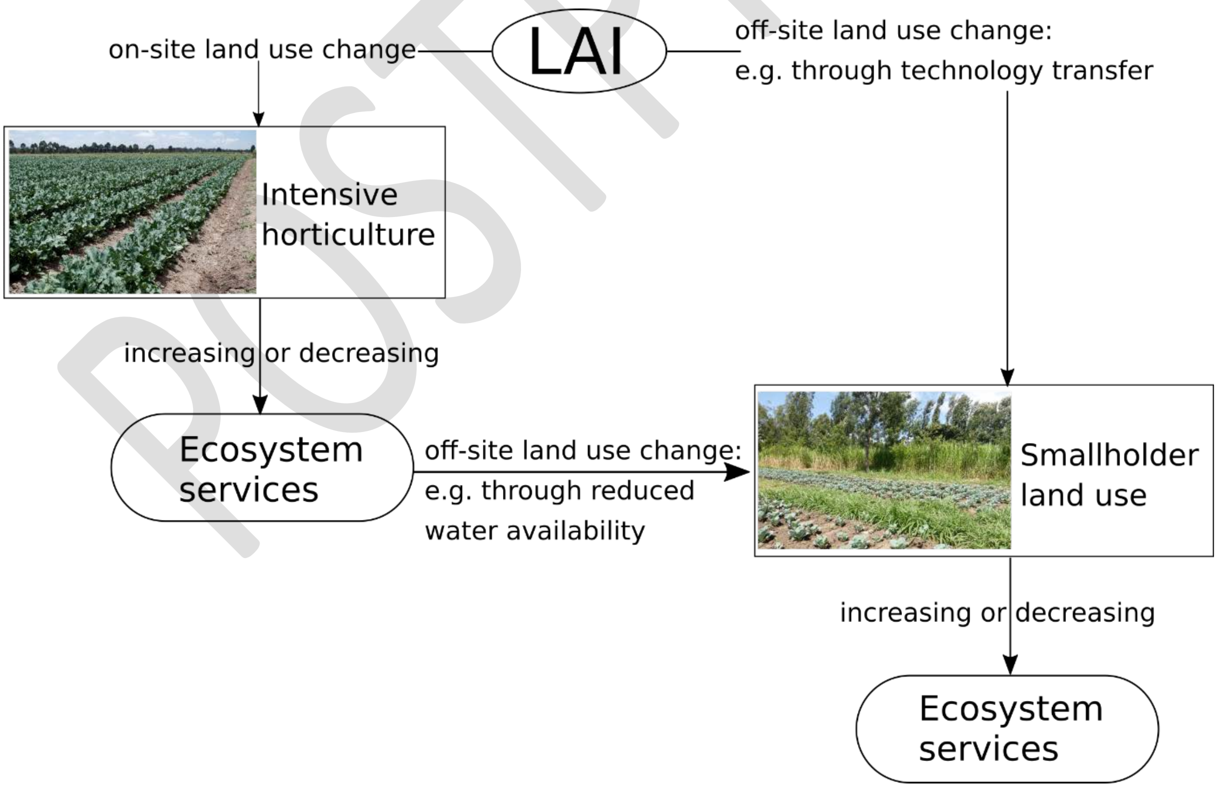

Fig. 2. Conceptual framework illustrating how LAIs affect ecosystem services through on-site and off-site land use changes.

2.3. Land cover and land use change

In order to assess off-site land cover and land use changes—one of the potential impacts of LAIs—we analyzed land cover and land use change within a 5-km buffer area around the premises of each of the five selected LAIs between 1987, 2002, and 2016. The premises of several LAIs that were not part of our assessment were excluded from the buffer areas. For this reason, and due to the varying shapes and sizes of the five selected LAIs' premises, the 5-km buffer areas analyzed differed in size, ranging between 7,908 and 12,532 hectares. The land cover and land use maps were generated by means of a supervised classification of Landsat satellite data. The kappa accuracies of the three classifications range between 78.3% and 82.1%, with values >80% considered a strong level of agreement (Congalton and Green, 2008; McHugh, 2012). F1 scores range between 83.6% and 87.8%. Detailed information on the classification and validation methods are provided in Eckert et al. (2017). Changes in land cover and land use were assessed by applying a post-classification pixel-to-pixel comparison and creating cross-tabulation matrices for the periods from 1987 to 2002 and from 2002 to 2016. We present stable areas, area losses, and area gains for each land cover and land use class to show how that land cover and land use class increased and decreased in different parts of the buffer areas. As the five analyzed buffer areas vary in size, we present the changes as a percentage of the total analyzed area per LAI. In addition, we analyzed net changes in the three small land cover and land use classes of greenhouses, waterbodies, and built-up areas not only in the 5-km buffer areas around the selected LAIs but also on the premises of the selected LAIs.

2.4. Small-scale farmer interviews

Further, we randomly selected 20 households in the vicinity of each of the five LAIs to be interviewed. This was done by generating 20 random coordinates in ArcGIS within a 2-km buffer around each LAI's premises. Fieldwork was conducted between January and February 2017 by three teams of Kenyan enumerators. The enumerators selected the household closest to each random point for an interview if the household head was present and agreed to participate. If not, they moved to the next closest household. The interview guide contained both closed and open questions and was structured along the following topics: (1) household characteristics and involvement with the LAI; (2) land use changes and their links to the LAI; and (3) perceptions of direct impacts of the LAI on the environment and on human well-being (Appendix 1). The interview guide was pretested on eight households that were not included in the sample used for the analysis. Interviews lasted between 45 minutes and two hours. They were held in either Kikuyu, Kimeru, or Kiswahili; respondents' answers were directly translated into English and recorded in writing. Qualitative information was coded by the main author and transferred to an Excel database for statistical analysis. We calculated frequencies of responses using the R statistical software (R Core Team, 2015) and compared them between the five LAIs.

3. Results

3.1. Perceived impacts of LAIs on small-scale farmers' land use and the overall environment

3.1.1. Involvement of interviewed households with LAIs

The respondents had an average age of 46, and 54% were women (see Table A2.1 for details). The average household size was 4.8 (+/- 2.5) people. All interviewed households except one engaged in crop farming. While 22% (n=98) did so exclusively for subsistence, the other 79% sold an average three quarters of their produce. None of the households produced exclusively for the market. Overall, the main crops were potatoes, maize, and beans, although households near LAI1, where the climate is more humid, produced wheat instead of maize for subsistence (for the labelling of LAIs see

Table ***1*** and Fig. 1). Other crops included green leafy vegetables (cabbage, kale, and spinach), legumes (peas), root vegetables (carrots, cassava, and onions), fruit shrubs (tomatoes and capsicum), and pumpkins. While about 40% (n=79) of households sold their crops to brokers collecting them at the farm gate, another 40% of households sold their produce on the market. Only seven of the interviewed households sold their crops to an LAI. Six of them were in a contract farming scheme to produce French beans or cabbage for LAI4, whereas one household produced French beans for an LAI not included in our sample. As many as 89% of households owned livestock, mainly cows, sheep, and goats. At 44% (n=89), almost half of these households exclusively stall-fed their livestock. About 33% had their own grazing land, and 11% used communal grazing land. The remaining households either combined the use of grazing land and stall-feeding (6%), or grazed their animals inside their own or other peoples' farm compounds (6%).

Only 14% (n=100) of the respondents were born in the area. While 32% moved to the region more than 20 years ago; 23% arrived between 1997 and 2007, and another 22% between 2007 and 2012. About 9% settled in the area during the past five years. The main reasons for moving to the area were the need for land to farm (37%; n=85) or marriage in the area (18%). Potential job opportunities with LAIs were not among the reasons cited. Only 10% of all interviewed households (n=100) had a member currently working for the nearby LAI company, and 5% had a member working for a different LAI company in the study area. While another 20% of households had previously had members working for the nearby LAI company, 65% of the households had never had a member employed by an LAI enterprise. The main reasons cited were that land users preferred to work on their own farms (26%; n=65); that they were generally not interested in working for an LAI company (25%); and that they ran their own business or were employed elsewhere (23%). Another 14% of households who had never worked for an LAI enterprise stated that they feared bad working conditions or negative impacts on their health. Only four households stated that they would like to work for the nearby LAI company but that it was difficult to find a job.

3.1.2. Perceived land cover and land use changes and their relation to LAIs

Land users reported perceived changes in the size and management of cropland and grazing land, as well as in tree cover. Looking at cropland changes, about half of the crop-producing households had changed the size of their cropland area since they had begun to grow crops (Table 2). About half of these households had expanded their cropland, while the other half had reduced it. Overall, new cropland had been established mainly on bush- and shrubland or grazing land; in the vicinity of LAI1, three out of five households who had expanded their cropland had expanded it into former wheat cultivation areas. Only one household had established new cropland in the forest. Households who had reduced the size of their cropland had mainly used it to construct homesteads or had converted it into grazing land. In some cases, it had remained cropland, but was now used by a different land user. Cropland reduction was related to the LAI only in one single case, where the LAI company had purchased a small share of a household's cropland to establish greenhouses. Other than that, the main reasons for households to reduce cropland size (n=26) were environmental factors, such as a decrease in rainfall (23%), the lack of a market for their products (19%), the sale of land (15%), reduced productivity (12%), or the need to leave certain plots fallow (12%).

Table 2. Perceived changes in the size of cropland and grazing land near the different LAIs. HH = households.

	Overall (n=99)	**LAI1 (n=20)**	**LAI2 (n=20)**	**LAI3 (n=20)**	**LAI4 (n=19)**	**LAI5 (n=20)**
Change in size of cropland (% of HH with cropland)	**51**	**45**	**55**	**40**	**42**	**70**
Increase (% of HH with cropland)	24	25	30	15	26	25
Decrease (% of HH with cropland)	26	20	25	25	16	45
	Overall (n=44)	**LAI1 (n=6)**	**LAI2 (n=10)**	**LAI3 (n=7)**	**LAI4 (n=11)**	**LAI5 (n=10)**

Change in size of grazing land (% of HH with grazing land)	**27**	**33**	**10**	**29**	**18**	**50**
Increase (% of HH with grazing land)	14	17	0	0	9	40
Decrease (% of HH with grazing land)	14	17	10	29	9	10

About two thirds of all respondents (67%; n=100) reported a change in their cropland management practices. Of these respondents (n=67), 40% had changed their seed varieties, which a large majority of them perceived to have increased crop production and crop yield; almost half of them also reported that the change had improved soil quality (see Table A2.2). Another widespread change was a change or abandonment of crops (34%), which respondents associated with differing impacts on crop production, crop yield, crop diversity, soil quality, and water use. Another 18% of respondents who had changed their cropland management practices reported that they applied less irrigation, which they largely perceived to have adverse effects on crop yield, crop production, and crop diversity, whereas it enabled water savings. Finally, 16% had begun to use a tractor. This was perceived to increase crop production while hardly affecting soil quality. The main reasons by far for changing cropland management practices were lack of water (29%) and the need to increase production (8%).

Among all respondents who reported having changed their cropland management practices (n=67), 27% attributed this change to the LAI (Table 3). The negative impacts of LAIs that had caused land users to change their cropland management practices were all of the environmental kind, whereas the very few positive impacts mentioned were related to economic opportunities and knowledge transfer. Negative impacts causing cropland management change had occurred in the vicinity of all LAIs, but predominantly so near LAI3, which produces flowers. The most-cited reason for changing cropland management practices was the over-abstraction of river water by the LAI company, which was mainly reported in relation with LAI3. Households around this LAI had stopped irrigating their crops or had switched to crops requiring less water. One household had started using drip irrigation, while another one (near LAI4) had dug a well to increase its own water supply. Another reason was the perceived increase in insect and bird pests on small-scale farmers' land. Respondents explained that this was due to the increased use of pesticides by the LAI companies, which drove the pests into the surrounding small-scale farms' cropland. Two households near LAI2 stated that polluted effluents from the LAI premises had caused them to abandon potato farming. Another two households near LAI1, a floriculture enterprise, had the impression that rainfall had decreased due to the greenhouses set up by the LAI company; in response, they had started to irrigate their crops and to use chemicals and crop rotation, respectively. Two respondents perceived LAIs as having a positive impact on their cropland management, thanks to training provided by an LAI company not included in our sample, or because their nearby LAI had provided the opportunity to obtain an outgrower contract.

Table 3. Impacts of LAIs on small-scale farmers' cropland management practices. HH = households; n=number of respondents who reported a cropland management change; several responses possible.

	LAI impacts on cropland management	**Overall number of HH reporting cropland manage-ment change (n=67)**	**LAI1 (n=10)**	**LAI2 (n13)**	**LAI3 (n=16)**	**LAI4 (n=11)**	**LAI5 (n=17)**
Negative impacts	Over-abstraction of river water by LAI company	6			5	1	
	Increase in pests	3		1	2		

	Water pollution	2		2			
	Reduced rainfall due to greenhouses	2	2				
	LAI company has no demand for small-scale farmers’ crops	1					1
	Presence of LAI resulted in poor harvest	1			1		
Positive impacts	Outgrower contract	1				1	
	Extension services	1	1				

Among the households with members who were currently working for an LAI company or had done so in the past (n=35), only six reported that they had gained knowledge they found useful for their own crop cultivation. At two of the floriculture LAIs, employees had learned about integrated pest management, crop rotation, the use of organic manure, and livestock keeping, while one respondent working for a horticulture LAI had learned about horticultural practices.

Looking at changes in the size or management of grazing land, almost all respondents using their own or communal grazing land (n=39) reported that it had changed in size since they had begun to use it. While some of them had converted grazing land into cropland (8%), others had done the opposite (5%). One respondent reported a decrease in grazing land due to LAI4, whose operators had bought communal grazing land to establish greenhouses. Of the 39 respondents using grazing land, 28% reported a change in their grazing practices. The majority of these (18%) had increased stall-feeding due to drought and pasture degradation resulting from overgrazing. Few respondents had adopted rotational grazing to reduce damage from overgrazing (5%), changed the cattle breed to increase milk production (3%), or abandoned livestock keeping altogether for personal reasons (5%).

Finally, regarding changes in tree cover, nearly all respondents (97%) perceived changes in the spatial extent of tree cover throughout the landscape. As many as 43% of them (n=97) had noticed that the natural tree cover had decreased (since about 2009 on average), while another 12% mentioned a decrease in planted trees. At the same time, 40% perceived an increase of planted trees (since about 2006 on average) in the form of larger plantations as well as single trees in peoples’ fields. The main reason given for the decrease in natural tree cover was the exploitation of forests for firewood, charcoal production, and timber (74%; n=42). Clearing forested land for settlements or cropland was mentioned as an additional important reason (17%). The decrease in planted vegetation was also mainly attributed to the exploitation of forests for firewood, charcoal production, and timber (67%; n=12). Only two respondents associated the decrease in tree cover with the presence of LAIs, explaining it with LAI companies’ increased demand for construction wood. Perceived increases in tree cover were attributed to increased tree planting in response to a growing demand for wood-based energy and construction wood (38%; n=39); as well as for other purposes such as windbreaks (25%; n=39), shade (13%; n=39), and for the trees’ aesthetic value (13%; n=39). Two respondents related the increase in tree plantations to LAI1, saying that its operators had planted trees as windbreaks and distributed tree seedlings to farmers.

Despite the perceived decrease in natural tree cover, 81% of all respondents (n=100) confirmed that natural tree cover was still available in their surroundings. We asked these respondents if they benefitted from any of the following five provisioning ecosystem services provided by forests: timber, firewood, wild fruits, medicinal plants, and freshwater. At 52% (n=81), a majority of respondents said they collected firewood in forests, and 15% (n=81) said they obtained freshwater (see Table A2.3). The remaining three ecosystem services were much less important. However, when asked about other benefits provided by forests, respondents came up with a long list of additional ecosystem services. The main ones, each mentioned by at least five respondents (n=81), were the attraction of rainfall (33%), use as pasture (16%), use as a windbreak (10%), air purification (9%), use as a tourist attraction (9%), use for beekeeping (7%), and use as a land reserve for future cropland expansion (7%) (Table A2.3). The main consequence perceived by those respondents who said that natural forest was no longer available in their surroundings (n=19) was reduced rainfall and water availability (84%) (Table A2.4).

3.1.3. Perceived direct impacts of LAIs

When asked about the impact of the neighboring LAI on their household, respondents voiced many and diverse perceptions (Fig3). However, these did not differ much between the five LAIs. Positive impacts were perceived by 23% of the total sample of respondents (n=100), negative impacts by 30%, both positive and negative impacts by 22%, and no impacts at all by 25%. More than 80% of respondents (n=98) perceived the nearby LAI to have impacted on the environment, with fewer environmental impacts perceived near the two horticulture LAIs (LAI4 and LAI5) than near the three floriculture LAIs (LAI1, LAI2, and LAI3). The percentage of respondents who perceived a general impact of the nearby LAI on peoples' health was 59% for the overall sample (n=100). Like in the case of environmental impacts, the three floriculture LAIs were perceived to have impacted on people's health by a higher percentage of respondents than the two horticulture LAIs. Only 28% of the respondents (n=97) confirmed that the nearby LAI company had provided infrastructure to the community; this was the case with LAI1, LAI2, and LAI4. Almost half of all respondents (49%; n=100) reported that there had been conflicts between the LAI operators and the neighboring communities. This was most pronounced for LAI1 and LAI2 (floriculture) and much less for LAI4 (horticulture). However, when asked whether they would prefer for the nearby LAI company to remain or to leave, between 70% and 95% of respondents near each LAI said they would prefer for the company to remain.

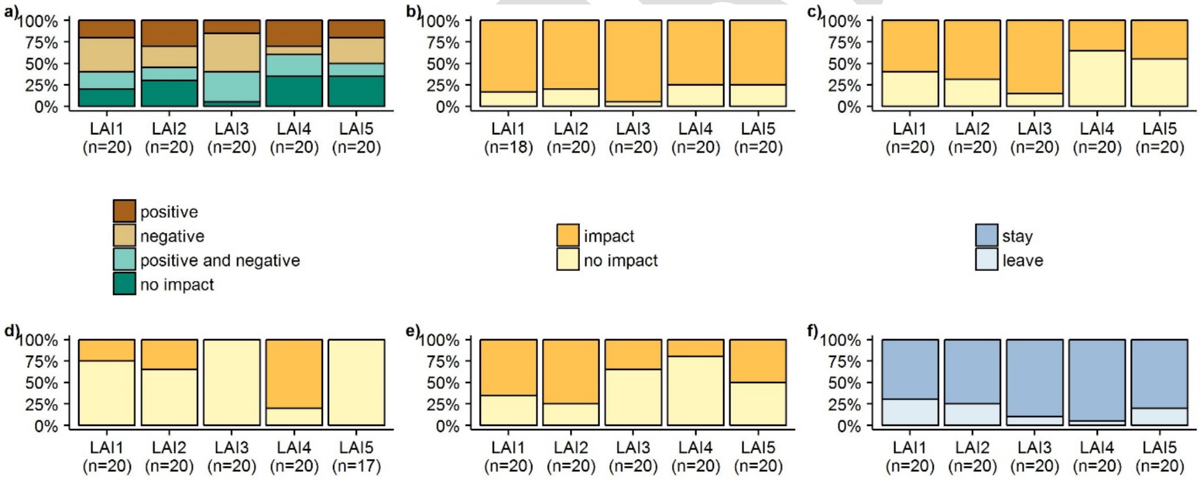

Fig. 3. Perceived direct impacts of LAIs on (a) households, (b) the environment, (c) people's health, (d) infrastructure, and (e) conflicts, as well as (f) overall preference of households for LAI companies to remain or leave, all expressed as percentages of households reporting impacts or no impacts (a–e) or a certain preference (f).

Overall, respondents (n=100) mentioned several positive spillovers of LAIs on their households, including income opportunities from employment (18%), improved general security in the area (8%), improved infrastructure (7%), improved market opportunities for the population (7%), and outgrower contracts (5%) (Table 4).

Among the negative impacts of LAIs on households, environmental ones were reported most frequently (Table 4). The most widely perceived negative impact, mentioned by 14% of the respondents (n=100), was air pollution with chemicals that were being sprayed on LAI cropland. This was an issue near all five LAIs. Almost as frequently, respondents mentioned a perceived increase in insect and bird pests on their land (12%) as a result of the LAI company applying pesticides and driving the pests into the surrounding cropland. Over-abstraction of river water by LAI companies was mentioned by 11% of all respondents, especially near LAI3 (floriculture) and LAI4 (horticulture) and less so near LAI1 and LAI5; LAI2 was perceived not to have any household-level impact in this regard. Effluents discharged by the LAI farms that polluted the river or groundwater with chemicals was another major impact on households (9%) that was perceived near LAI2 and LAI3 (floriculture) and, to a lesser degree, near LAI5 (horticulture), whereas LAI1 and LAI4 were not perceived to have this impact.

When asked specifically about perceived environmental impacts of the LAIs, almost half of all respondents (48%; n=98) said that air pollution was an issue. This was mentioned more frequently near the three floriculture LAIs, especially near LAI2, and less near the two horticulture LAIs. The over-abstraction of river water by the LAI company was the second most common environmental impact, reported by 20% of all respondents. Only 5% perceived water pollution with chemicals to be an issue; this was mentioned especially near LAI2 (floriculture) and LAI5 (horticulture). Other environmental impacts were mentioned much less frequently. One respondent reported a positive environmental impact as a result of one of the floriculture LAIs planting trees.

Regarding perceived impacts of LAIs on peoples' health, 33% of the respondents (n=100), mainly near the three floriculture LAIs, observed that people suffered from respiratory problems due to the inhalation of chemicals. This was specified by 12% of respondents who said that employees of the LAI farm—especially LAI1—were exposed to chemicals during working hours. Only one respondent mentioned positive impacts on health, namely improved nutrition and improved health infrastructure.

Improved school buildings were the main perceived impact of LAIs on infrastructure (14%; n=97), though this was mentioned only in the cases of LAI4 (55%; n=20) and LAI2 (15%; n=20). According to respondents' perception, the operators of LAI1 had only built a motorcycle shed (15%; n=20), while those of LAI2 had invested in road construction (10%; n=20), a laboratory at the local school (10%; n=20), and electricity supply (5%). The operators of LAI4 had built a dispensary (15%; n=20), improved water supply for the local population (5%), and provided support to the local police station (5%).

The interviews also revealed several sources of conflict between the five LAIs and the nearby communities, with 18% of respondents (n=100) near all LAIs except LAI2 reporting conflicts related to water use. Further sources of conflict mentioned by respondents were polluted wastewater (12%) and bad working conditions (6%). Interestingly, LAI2 (floriculture), while not associated with conflicts over water use, had the highest percentage of respondents (60%; n=20) associating it with conflicts over polluted wastewater. Despite the number of negative impacts perceived by nearby small-scale farmers, 82% (n=100) of them said they would prefer for the LAIs to remain in place. Overall, 68% of respondents (n=100) considered the LAIs to be a source of employment. The main reason why some respondents said they would prefer the nearby LAI to leave was that its disadvantages outweighed its benefits.

Table 4. Main perceived direct impacts of the five LAIs on households, the environment, peoples' health, infrastructure, and conflicts, with the percentage of households mentioning each impact. Several responses were possible. Only impacts mentioned by at least 5% of the overall sample are shown here; the full results are provided in Table A2.5. HH = households.

		LAI impacts (% of HH)	**Overall (n=100)**	**LAI1 (n=20)**	**LAI2 (n=20)**	**LAI3 (n=20)**	**LAI4 (n=20)**	**LAI5 (n=20)**
On households	Positive	Employment/income	18	20	15	30	15	10
		Improved security	8	5	10	10	0	15
		Improved infrastructure	7	5	10	10	5	5
		Improved market opportunities	7	20	5	5	5	0
		Outgrower contracts	5	0	0	0	25	0

	Negative	Air pollution with chemicals	14	25	5	20	5	15
		Increase in pests (insects, birds)	12	5	5	25	5	15
		Over-abstraction of river water by LAI company	11	5	0	25	20	5
		Effluents released into water	9	0	30	10	0	5
			Overall (n=98)	**LAI1 (n=18)**	**LAI2 (n=20)**	**LAI3 (n=20)**	**LAI4 (n=20)**	**LAI5 (n=20)**
On the environment	Negative	Air pollution with chemicals	48	45	70	55	30	40
		Over-abstraction of river water by LAI company	20	0	10	40	35	15
		Water pollution with chemicals	5	0	15	0	0	10
			Overall (n=100)	**LAI1 (n=20)**	**LAI2 (n=20)**	**LAI3 (n=20)**	**LAI4 (n=20)**	**LAI5 (n=20)**
On peoples' health	Negative	Respiratory problems	33	20	40	65	15	15
		Exposure to chemicals	12	35	5	5	10	5
			Overall (n=97)	**LAI1 (n=20)**	**LAI2 (n=20)**	**LAI3 (n=20)**	**LAI4 (n=20)**	**LAI5 (n=17)**
On infrastructure	Positive	School buildings	14	0	15	0	55	0
			Overall (n=100)	**LAI1 (n=20)**	**LAI2 (n=20)**	**LAI3 (n=20)**	**LAI4 (n=20)**	**LAI5 (n=20)**
On conflicts	Negative	Water conflicts	18	20	0	30	20	20
		Polluted wastewater	12	0	60	0	0	0
		Bad working conditions	6	30	0	0	0	0

3.2. Land cover and land use change in the vicinity of LAIs

Our analysis of remotely sensed land cover and land use data for the two periods from 1987 to 2002 and from 2002 to 2016 revealed that net area changes in the various land cover and land use classes within the 5-km buffer areas around each LAI were generally small, whereas losses and gains of the same land cover and land use classes in different parts of the buffer areas were common (Fig. 4). During both periods, rainfed cropland was the most common land cover and land use class in the area around LAI1, and savannah grassland dominated in the areas around LAI3, LAI4, and LAI5. In the buffer area around LAI2, savannah grassland was the most common class in 1987, whereas forest (including both natural tree cover and plantations) dominated from 2002 onwards.

Between 1987 and 2002, rainfed and irrigated cropland experienced a slight increase or remained stable around all of the LAIs. Between 2002 and 2016, rainfed cropland decreased around LAI1, LAI2, LAI3, and LAI4, whereas it increased around LAI5. During the same interval, irrigated cropland increased around LAI1, and LAI5 and remained stable or decreased slightly around LAI2, LAI3, and LAI4. Forest increased slightly around all LAIs during both intervals, except around LAI5, where it remained stable between 1987 and 2002. Bush- and shrubland covered very small areas around all LAIs except LAI4. Here, it remained the second most dominant land cover and land use class even though it decreased between 2002 and 2016. Around LAI2, LAI3, and LAI4, savannah grassland decreased during the first interval and increased again during the second. In the vicinity of LAI1, savannah grassland decreased slightly during both intervals, and around LAI5 it remained stable between 1987 and 2002 but then experienced a major decrease between 2002 and 2016.

Furthermore, changes occurred in three land cover and land use classes that cover comparatively small areas and are therefore not shown in Fig. 4. First, 79 hectares of greenhouses were established between 2002 and 2016, of which 85% are located in the 5-km buffer area around LAI1. Second, the area covered by surface waterbodies increased from a total 26 hectares in 1987 to 37 hectares in 2016. Third, built-up areas increased from 69 hectares in 1987 to 183 hectares in 2016. This class may actually be underestimated in our analysis, as the Landsat data may not have captured single small farm buildings adequately.

For the latter three land cover and land use classes, we also assessed changes on the actual premises of the five assessed LAIs. Here, a total 94 ha of greenhouses were established between 2002 and 2016. This was accompanied by the appearance of a total 19 additional hectares of waterbodies during the same period. Built-up areas increased from 1.5 to 14 hectares in total between 2002 and 2016, with this change happening almost entirely on the premises of LAI4.

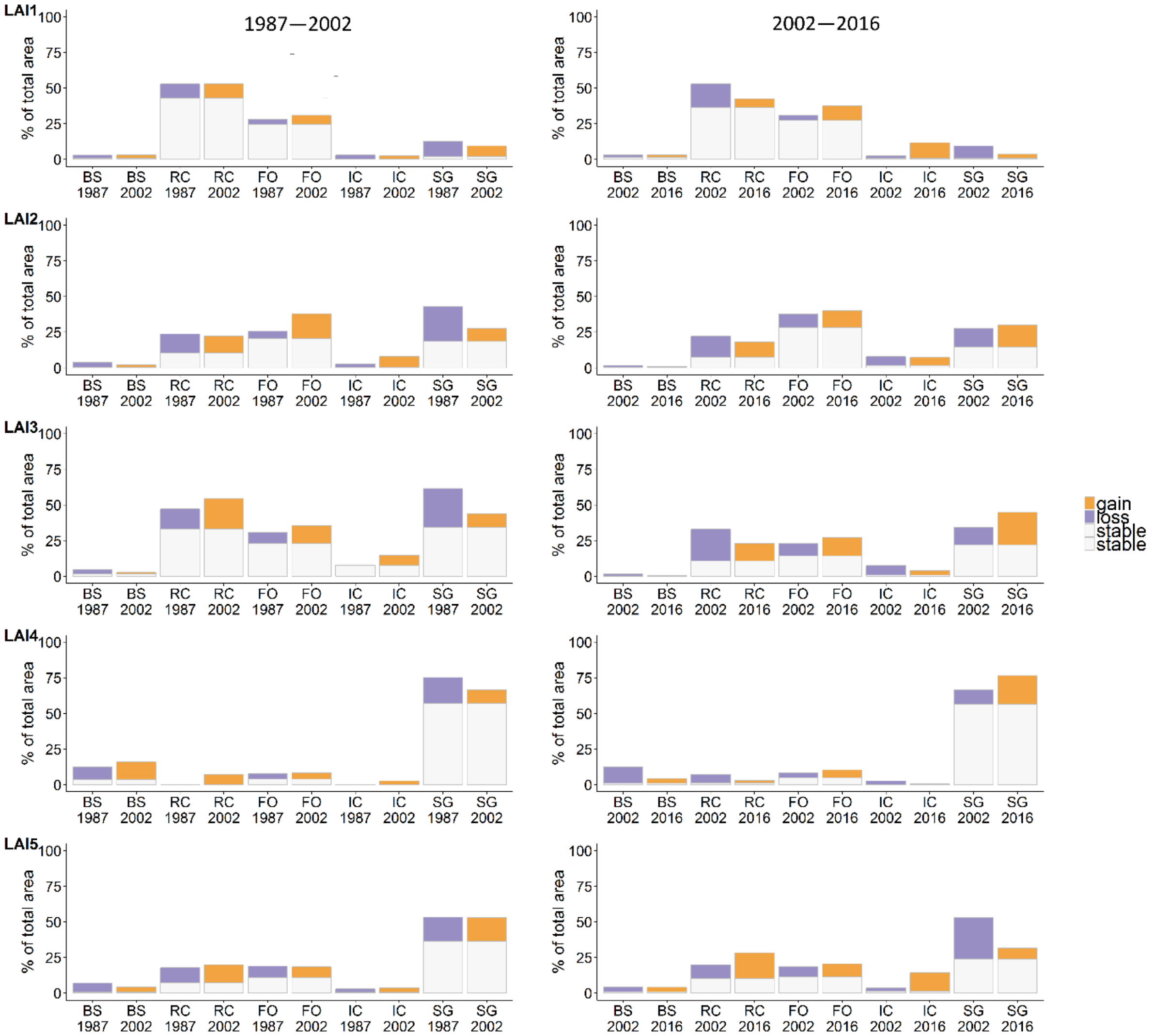

Fig. 4. Stable areas, losses, and gains of each land cover and land use class within a 5-km buffer area around each of the five LAIs in percent of the total buffer area analyzed for that LAI. BS=Bush- and shrubland; RC=Rainfed cropland; FO=Forest; IC=Irrigated cropland; SG=Savannah grassland.

4. Discussion

Our study indicates that the presence of LAIs in a diverse landscape dominated by small-scale agriculture has wide-ranging impacts on the surrounding social-ecological systems, even if the majority of small-scale farmers is not directly involved with them. Despite the high density of LAIs in our study area and the fact that they constitute the single most important employment generator in the area northwest of Mount Kenya (Kiteme et al., 2008), only about one-third of the households interviewed had a member who was, or had been, employed by an LAI company. Although more than half of the respondents had settled in the area less than 20 years ago, the presence of LAIs was not the reason why they came to the region. Apart from very few professionally qualified employees, LAI companies employ their workers on a casual basis; therefore, many farmers view employment opportunities with the nearby LAI company either as a safety net in times of crop failure or as a means to complement on-farm activities when they need additional income. This is confirmed by the fact that all households with a member currently employed by an LAI company had continued to produce their own crops for subsistence and commercial purposes. These findings suggest that, despite the increasing commercialization of agriculture, our study area is not currently experiencing a “depeasantization process” (Ploeg, 2010). Observations similar to ours were made by Smalley and Corbera (2012) for Pokomo farmers near the Tana Integrated Sugar Project in the Tana River Delta. Generally, most households prefer to cultivate their own fields rather than entering into a work relationship with an LAI company. One of the reasons might be the generally good market access for smallholders’ produce, which is mostly picked up by brokers directly at the farm gate. The relatively low wages and negative health impacts generally associated with the LAIs are other reasons why people refrain from taking up a job at a large-scale flower or vegetable farm. In our sample, only five respondents had obtained an outgrower contract with an LAI company. These farmers received higher or fixed prices for their crops, making this arrangement more attractive than selling the crops to brokers or on the market. However, other studies have shown that the potential of outgrower schemes for poverty alleviation needs to be critically examined (Oya, 2012).

We have analyzed small-scale farmers’ perceptions of land use changes and direct impacts of LAIs in different contexts. The five floriculture and horticulture LAIs we studied did not result in any uncompensated land loss for small-scale farmers. This has two main reasons. First, existing land tenure rights of Kenyan small-scale farmers in the area are largely based on a freehold system. This type of tenure confers to the holder absolute ownership of land for life, and can only be acquired through the willing buyer–willing seller principle. Second, and most importantly, the majority of LAIs were established on former large-scale colonial farms and ranches, and not on land cultivated by small-scale farmers. This is a consequence of the Mount Kenya region’s history, which differs from that of other regions in Africa experiencing a proliferation of LAIs. We found no clear trend regarding expansion or reduction of smallholders’ cropland as a result of the LAIs. While some land users had expanded their cropland through inheritance, purchase, or lease, others used cropland to build homesteads or converted it into grazing land. Conversion into grazing land was mainly triggered by perceived drought and cropland degradation, which made it economically more sensible for farmers to switch to livestock production. The analysis of remotely sensed land cover and land use data did not reveal a clear trend either, with rainfed cropland decreasing around most LAIs and irrigated cropland increasing around two but decreasing around the other three LAIs. However, a landscape-scale analysis of the entire area northwest of Mount Kenya revealed a clear increase in rainfed and irrigated cropland over the last 30 years (Eckert et al., 2017). For grazing land we were unable to detect a clear trend, whether based on peoples’ perceptions or via the satellite data. As revealed by the satellite data analysis, tree cover in the form of plantations increased over both time intervals, especially around the three floriculture LAIs. Around LAI1 and LAI3, a majority of respondents had perceived this increase in planted trees, whereas around the other LAIs more respondents felt that especially natural tree cover had decreased. Farmers perceived the loss of tree cover to have a range of negative impacts, with decreasing water availability being the main concern. This reflects the importance of sufficient rainfall and river water flow for crop cultivation in this semiarid to semihumid zone. Greenhouses increased not only on the premises of the LAIs assessed but also in the areas surrounding them. As they occur in clusters, it is unlikely that they were established by smallholders. More likely, they belong to other large-scale farming enterprises that were not identified as such in our assessment and were therefore not excluded from the analyzed buffer areas. Waterbodies also increased both on the premises of the assessed LAIs and in the surrounding areas. Based on their location, we assume this shows that LAIs as well as smallholders are adapting to the increasing demand for water in the region. The use of remotely sensed data to detect off-site impacts of LAIs on land use was challenging, as these impacts occurred mainly at the plot level and in the form of crop management changes. Large-scale land use changes that were detectable in the satellite data could not be directly linked to the existing LAIs based on respondents' statements.

It is widely presumed that LAIs influence the agricultural practices of smallholders mainly via their exposure to new agricultural tools and knowledge. In our case, however, only about one-fifth of the respondents with household members who had been directly exposed to an LAI had adopted new agricultural technologies and implemented them on their farms. Interestingly, several of the respondents who reported having gained knowledge from their involvement with an LAI worked, or had worked, for a floriculture farm. This shows that knowledge transfer is not restricted to LAI enterprises growing the same crops as the surrounding small-scale land users (Deininger and Xia, 2016). The LAIs were widely perceived to have negative impacts on the environment, which then caused some of the respondents to adapt their cropland management strategies. The main driver of changes in cropland management practices was the perceived lack of irrigation water, which a number of land users attributed to the over-abstraction of river water by LAI companies. Around LAI1, which only uses groundwater and harvested rainwater, land users did not attribute reduced river water flow to the LAI. This is a good indicator that the interviewed households did not generally blame the LAIs for all environmental changes experienced. The main source of conflict by far between small-scale farmers and LAI companies was the use of river water for irrigation. Water conflicts were present around most LAIs, although only around one of the flower farms (LAI3) were they so severe that land users had decided to abandon or reduce irrigation farming. Given that this LAI company uses a self-regulating weir, which makes it impossible to abstract more than what is available during the flood flow season, it is likely that the escalated water conflicts in the area result from excessive irrigation activities among the smallholders themselves. This suggests a need for quantitative studies comparing LAI companies' and small-scale farmers' water use efficiency before the water crisis can be blamed entirely on LAIs. Over the last decade, LAIs have invested heavily in the construction of rainwater harvesting dams (Eckert et al., 2017), thereby reducing their dependency on river water by about 30% between 2003 and 2013 (Lanari, 2014; Lanari et al., 2016). At the same time, irrigation on small-scale farmers' cropland has increased, and it remains unclear who uses how much water. However, water is clearly the main factor limiting agricultural production in the region, and the proliferation of LAIs coupled with massive population growth has exacerbated the shortage of this valuable resource (Kiteme et al., 2008; Wiesmann et al., 2000). Negotiations over a fair distribution of water between LAI companies and small-scale farmers, which are already being facilitated by the local water resources users associations, need to be strengthened and fostered on behalf of more sustainable development in the region. Some small-scale land users said they had adapted their crop management to perceived negative impacts of LAIs on water quality and the presence of pests. Muriithi and Yu (2015) have shown that heavy metal concentrations peaked in rivers surrounded by LAIs or intensive small-scale farming. While they linked this to the use of phosphate fertilizers and copper-based agrochemicals used in intensive farming, they were unable to clearly attribute the pollution to a specific actor. Again, while water quality is clearly an issue of concern in the area, both LAIs and small-scale farmers influence it via their respective farming practices. The ways in which small-scale farmers react to changes in their environment are manifold and have a wide range of impacts on ecosystem services such as soil properties or agrobiodiversity. Although most small-scale farmers' fields are no larger than about 1 hectare, the impacts of changes in their farming practices on ecosystem services may be wide-ranging, due to the large number of farmers adapting their practices in response to perceived negative impacts of LAIs. However, small-scale farmers' land use and crop management practices are generally highly dynamic and are influenced by various other factors besides the presence of LAIs.

Overall, our respondents perceived their nearby LAIs to have a wide variety of impacts. Among the positive spillovers, increased employment opportunities, security, infrastructure, and market opportunities were mentioned most. This is in line with the findings of Ulrich (2014) in the same region. Regarding negative impacts, small-scale farmers most frequently felt harmed by environmental impacts ranging from air pollution with chemicals to an increase in pests and increased water scarcity. This shows impressively that while water scarcity is an important environmental issue to address due to its impact on smallholders' agricultural production and food security, air pollution from agrochemicals sprayed by LAIs is the more pressing issue when it comes to smallholders' health and well-being. Respiratory problems due to the spraying of pesticides was the main symptom of ill health reported by the interviewed land users, who all lived within 2 km distance from an LAI's premises. This symptom was also common among residents and horticultural workers in the Lake Naivasha region (Tsimbiri et al., 2015). Open conflicts between communities and LAI companies exist and are clearly attributable to specific LAIs, except for conflicts around water scarcity, which are present around all LAIs but one. Specific LAI companies had conflicts with smallholders over alleged water pollution and low wages. Even though the respondents perceived a wide range of negative impacts and only few community benefits, a large majority of them preferred for the nearby LAI company to remain in place because they felt that it contributed to the region's general economic development.

5. Conclusion

The present study adds to the scarce empirical data on impacts of LAIs on smallholders' livelihoods and the environment. Unlike in many other areas in Africa and elsewhere, in the Mount Kenya region LAIs did not lead to the displacement of smallholder farmers. However, the perceived decrease in available water resources has led many small-scale farmers to change their cropland management practices, with various further impacts on ecosystem services. Other environmental impacts, such as air and water pollution, are perceived to have a negative effect on people's health. Positive spillovers from LAIs onto small-scale farmers' land in the form of agricultural technologies or knowledge were scarce, which is mainly due to the limited percentage of small-scale farmers employed by LAI companies. Nevertheless, small-scale farmers generally appreciate the presence of LAIs in the region, as they are thought to provide employment opportunities and contribute to the region's wider economic development. If investors make further efforts to mitigate environmental impacts, address major water-related conflicts, and improve the working conditions of their casual employees, a peaceful coexistence of small-scale farmers and LAIs in the northwest of Mount Kenya may become quite conceivable.

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